EXAMINING WATER QUALITY MANAGEMENT ON LAKE CHAMPLAIN
THROUGH THE LENS OF *E. coli*

ENVS 401
PROJECT REPORT
ASHCRAFT, TROMBULAK, MUNROE
Cordelia Newbury, Terra Weiland, Kayla Bien, Emma Loizeaux, Lauren Yang

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EXECUTIVE SUMMARY

This report closely examines *E. coli* management strategies to inform an understanding of transboundary water quality management of Lake Champlain. By using one pollutant as a case study, we are able to broaden conclusions and recommendations to a transboundary, multi-pollutant scale. Currently, the coordination and collaboration in water quality management in Lake Champlain is muddied by the fact that the lake is governed by three political jurisdictions with public, political, and non-governmental stakeholders all who have differing values. This report first situates the regional context of Lake Champlain, then examines *E. coli* as an individual pollutant in the context of its stated regulations and standards, before framing the information in a broader context of transboundary pollutants in the lake. From this process, we offer a fresh perspective on transboundary water quality management and make recommendations that aim to improve overall water quality management and regulatory efficiency. In our conclusions, we illustrate obstacles in the current management system that make transboundary coordination difficult. Our recommendations respond to these obstacles in order to improve transboundary management and expand the term "transboundary" to incorporate new perspectives in the context of water quality management.

1. INTRODUCTION

This section introduces the setting, topic, and key actors of the report for the Environmental Studies 401 Senior Seminar at Middlebury College in Middlebury, VT. In addition, the project objectives and scope are detailed below.

1.1 Lake Champlain and Water Quality Management

"But one does not need to sail beyond the waters of Lake Champlain itself to find enjoyment to satisfy the most exacting. For here one can find, in the highest degree, experiences to satisfy both soul and sense. The lake is large enough to accommodate the yachtsman with a month's cruising, during which no day shall be a repetition of the preceding ones. Of all the lakes in our great country, Champlain is, by common consent of those acquainted with its characteristics, the most beautiful." (145)

-excerpt from Lake Champlain and Its Shore

W. H. H. Murray, 1890

This report examines the ecological and political transboundary challenge of managing water quality in Lake Champlain, which is situated in the Northeast, bordering Vermont, New York, and Québec. Managing the lake as a freshwater resource has proven difficult in the past due to a variety of factors such as the importance of the lake's public, economic, and cultural values; its particular susceptibility to pollution, along with the myriad of pollutant pathways to the lake; and ways in which those pollutants behave once in the lake. The lake has been heralded as an integral resource of the Northeast region for as long as settlement has existed in the area. There are countless values that locals and visitors place on the lake. From a resource for recreation to a source of drinking water, Lake Champlain is special in the direct connection the public feels with the lake. Standing on the Vermont shores, a resident can see the Adirondacks just to the west in New York, a distance surmountable by mere boat trip. Following the flow of the water north, Lake Champlain extends into Québec, where Missisquoi Bay provides recreational opportunities for southern Canadians. The water then continues north to connect to the Saint Lawrence River. The memories that individuals can create while using the lake for fishing, boating, swimming, or aesthetic value all contribute to an increased connection between the lake and those who use it.

Economically and culturally, the lake plays an important role in the historical narrative of this region's development. It is both a source of livelihood for the agriculture, forestry, fishing, and stone industries that rely on the natural resources of the lake for their incomes, as well as a main point of attraction for tourists who visit this area to revel in Lake Champlain's aesthetic beauty and recreational uses (Howland et al. 2006). Vermont, in particular, is heavily invested in Lake Champlain for drinking water and tourism. Vermont also uses the lake's resources for its

expansive agricultural industry, a sector that “generated about US $526 million in sales of agricultural products—such as milk, cheese, maple syrup, and apples—in 1997” (Howland et al. 2006:94). New York and Québec also utilize Lake Champlain for the similar purposes of industry, recreation, and tourism, however to a lesser degree, since the portion of the lake under Québec jurisdiction is quite small and New York has many other major water bodies that are focal points for industry and tourism.

Lake Champlain faces significant effluent pollution because its watershed to surface water ratio is much larger than those of other lakes, such as the Great Lakes. This means that the area in which the lake collects pollution is quite large, compared to how quickly pollution can be diluted. This also means that pollution is more visible in the lake, as there is more loading from the basin, which leads to challenging management demands (Winslow 2013). Vermont, New York and Québec strive to manage the water quality of the lake for the uses most relevant to each jurisdiction. Inevitably, discrepancies in standards and regulations have developed between the three governments, which reflect the differing uses and values placed on various parts of the lake.

Pollutants can enter Lake Champlain through a variety of means, such as point-source discharges, stormwater runoff, atmospheric deposition, and chemical dumping. How pollutants behave once in the lake—for example algal blooms and bioaccumulation in various levels of the food chain—further complicates water quality management as each pollutant requires different management strategies. All three jurisdictions are working to prevent pollution by increasing natural filters such as riparian buffers, updating infrastructure that might leak or overflow, and deterring individuals and industries from polluting the lake (ANR 2012). Total prevention, however, is perhaps impossible to achieve because of multiple stakeholders with conflicting interests. Therefore, we understand that water quality management (WQM) is a balancing act between these stakeholders, and that a successful management plan requires a comprehensive understanding of the various perspectives.

1.2 Project Objectives

Political priorities in Vermont, New York and Québec define how individuals can enjoy and use Lake Champlain. Therefore, this paper focuses on the relationship between these political priorities and the use of the lake, while using a particular pollutant—*E. coli*—as a case study. In this paper, our project objectives were to 1) characterize the regulatory approaches used by Vermont, New York and Québec to manage Lake Champlain water quality; 2) compare these approaches across the jurisdictions; 3) evaluate whether the approaches could benefit from increased coordination; and 4) make recommendations to improve transboundary water quality management of the lake. We begin our report with a brief discussion of stakeholders in this case, including our community partners, organizations intimately involved in the management of Lake Champlain. Next we provide some information on *E. coli* and discuss how and why we chose to

focus our project on this particular pollutant. In section three of this report, we address the nuts and bolts of water quality management with an analysis of regulatory goals in Vermont, New York and Québec, and more specifically a comparison of *E. coli* standards in the three jurisdictions. We move on to consider *E. coli* in the context of other pollutants in Lake Champlain and explore how management methods for *E. coli* may be applied to other pollutants. Finally, we discuss obstacles we have encountered in this research and offer recommendations for coordinated management that could help to overcome obstacles and create new approaches to water quality management in Lake Champlain.

1.3 Lake Stakeholders

Players in the lake range from individuals to groups to governing jurisdictions. Each brings their *own* perspective to how they would like to manage water quality, and what they would manage the lake for. The diversity of opinions at the table makes WQM challenging; however, it is also crucial to understand the various perspectives of the lake.

i. Jurisdictions as Stakeholders

The three political jurisdictions that govern Lake Champlain—New York, Vermont, and Québec—are all fundamentally committed to managing Lake Champlain to protect and preserve the water body as both a natural resource and as a hub of recreational activity. However, they all have different relationships with the lake. For example, geographic Lake Champlain only connects to a small percentage of the total area of New York, and is less economically profitable than other aquatic resources in that state. Similarly, Québec only directly connects to the small Missisquoi Bay portion of the lake, and even within this area, which encompasses approximately 19,150 acres of land, 58% of the Bay belongs to Vermont, and only the remaining 42% is governed by Québec (International Joint Commission). From this geographic standpoint, it is clear that New York and Québec have a lesser stake in Lake Champlain than Vermont, where the lake forms half of the state's western border.

Each of the three jurisdictions also has its own goals for the use of the lake. They also have differing values and stakes in the water's health and quality. In policy, all three jurisdictions use different language to express goals and standards. They use different classification, or categorization, systems to designate water usages and set the water quality standards. This diversity of goals and standards among the jurisdictions presents an interesting transboundary challenge for those coordinating water quality management for the lake as a whole.

ii. Non-Political Groups

In addition to these three jurisdictions, there are interest and advocacy groups that work to coordinate between the various departments and governments in order to improve lake water quality. The Lake Champlain Basin Program (LCBP) and the Lake Champlain Committee (LCC) are two non-profit organizations operating in this way. They have the capacity to address long-term and upcoming issues for the lake and work to preserve the lake's many resources through coordination with a variety of stakeholders, rather than relying on one particular perspective.

The two groups differ in their approaches to maintaining lake health. LCC is an advocacy group that uses science-based information to protect and improve Lake Champlain quality. Their advocacy role makes them important stakeholders as they can bring issues to the table that emerge from changing ecosystems and climates. Membership and donations finance the organization, and the LCC represents both New York and Vermont citizens. Although they are not directly involved with legislation, the LCC works with communities to educate and improve water quality.

The LCBP works in Québec as well as in New York and Vermont—they are committed to maintaining a thriving ecosystem in the Basin, providing healthy drinking water for inhabitants of Vermont, supporting diverse recreational uses, and monitoring general lake health with annual State of the Lake reports. The LCBP also works directly with government organizations to improve water quality. As their action plan, Opportunities for Action, outlines "the new plan identifies eight goals for Lake Champlain; chief among them are reducing phosphorus, preventing toxic contamination, managing aquatic invasive species, and implementing educational programs to increase public involvement in the stewardship of the lake" (LCBP 2013). As a government-funded organization, the Basin Program acts as a coordinating force between governments, local communities, and the private sector to reach water quality goals.

According to Mike Winslow of LCC, LCBP's strength lies in implementation of policy and action, whereas the LCC has stronger lobbying potential to put grassroots issues on the agenda. Together, these two community partners have been a great resource for better understanding existing policy and issues facing the lake. Each community partner has provided information on which pollutants have been thoroughly addressed and which could benefit from further investigation. These discussions have led to our choice of *E. coli* as a pollutant whose management may require more transboundary coordination.

iii. Public Stakeholders

Because Lake Champlain holds less industrial value than other large water bodies such as the Great Lakes, the relationship between residents, tourists and the natural landscape is more intimate and cultural. As such, the general public is an important stakeholder to consider when

studying water quality management of the lake. While there are many ardent environmentalists in the area who are devoted to water quality management that preserves natural ecology, there are also many individuals who appreciate the lake for its sheer aesthetic value and public resources, rather than for ecological integrity. Public stakeholders hold diverse interests in the lake and each relate to it differently, which makes targeting information and educational materials to this group of stakeholders challenging.

1.4 Focusing Scope

Though the three jurisdictions value Lake Champlain for slightly different services and uses, a healthy body of water is beneficial to all stakeholders involved. Maintenance and preservation of lake health involves extensive collaborative water quality monitoring across the three jurisdictions that share Lake Champlain. Ideally, there would be complementary policies regarding water quality standards and regulations between the three jurisdictions, so that the definitions and expectations of a 'healthy lake' could remain consistent throughout its waters and across borders. Transboundary coordination would reduce the effects of pollutants that spread to neighboring jurisdictions and would ensure a safe lake for all its users. Lake Champlain also possesses as much recreational value as it does industrial value, so safe recreation is an important priority for the three jurisdictions to respect and maintain.

Since water quality management involves many pollutants, environmental concerns, and political challenges, it has become important, in this project, to identify one water quality issue that can serve as a guide in developing a management framework that can be applied to other transboundary problems. Given the personal relationship users share with Lake Champlain, we have decided to focus on the indicator pathogen *E. coli*, a pollutant that threatens recreational opportunities and impacts public health, as a vehicle for developing a framework that assesses water quality management in Lake Champlain. Beach access and recreation are strong human values and contribute to the tourist economy of the basin. Using a pollutant with such social implications, we can look at and suggest improvements for how policy accommodates and interacts with the general public.

Our focused look at *E. coli* in the lake will allow this report to offer a series of recommendations and conclusions about not only the ecological imperatives to effective water quality management, but also the need for increased communication and coordination in the water quality management process. The intense study of one pollutant also allows for an in-depth understanding of the WQM logistics, while providing the scaffolding to understand other pollutants that trouble the waters of Lake Champlain and the difficulties associated with transboundary management.

2. *E. coli* AS A CASE STUDY

This section provides an in-depth profile on our chosen pollutant, E. coli. It also explains how this bacterium fits into our broader course theme of Transboundary Sustainability and illustrates the pollutant within the context of Lake Champlain.

2.1 *E. coli* as a Transboundary Issue

The scope of this project seeks to address a transboundary issue in sustainability. At first glance, *E. coli* may not seem like the most fitting case study, because unlike nutrient overloading, fecal contamination does not spread to distant stretches of the lake, and deposition is relatively localized. Although the pollutant is not a transboundary issue in terms of ecological behavior, we have broadened our definition of transboundary to include cultural and institutional facets that *do* cross political borders. The necessary coordination to address these social issues is an important component of water quality management, and has provided the opportunity to consider water quality from diverse perspectives.

One way we have abstracted the concept of "transboundary" is through our considerations of human mobility. Beach goers may live in Québec but swim in New York, especially when spending a day at the lake could involve boating across politically defined boundaries. On a lake that is easy to cross and travel around, cohesive management for the entire lake is especially pertinent. As such, it is important for communication and management standards to be coordinated across boundaries so that swimmers are exposed to the same amount of risk no matter where they are in the basin. In some ways, the health risk should be equal across any water body, but it is especially important when short term travel within a given water body is likely. Public health is a transboundary issue stemming from *E. coli* contamination; in order to keep all swimmers equally safe, risk assumption and standards should be equal across boundaries.

This interpretation of "transboundary issues" has broadened our understanding of how pollution and water quality affect people and the lake, and presents an interesting opportunity to think critically about improving water quality monitoring for many pollutants, even when they do not share similar biological characteristics. In particular, using *E. coli* as a case study for water management more broadly allows us to look at how institutions share and publicize water quality information, and to examine how communication among institutions and between professionals and the public can lead to improved lake health. Indications of poor conditions related to one pollutant such as *E. coli* can begin to unpack the intricacies of water quality management for the entire lake basin region, both from an institutional perspective and from a public standpoint.

2.2 *E. coli* as a Pollutant

Escherichia coli is a bacterium present in the gastrointestinal tracts of warm-blooded mammals. The strain *E. coli* 0157:H7 presents a health risk to the gastrointestinal systems of those who ingest it. Ingesting even as few as ten organisms of this strain can lead to gastrointestinal discomfort and illness, which explains many stakeholders' interests in keeping its levels in the lake low (Chart 2000).

Although publicly funded beaches must test waters in summer months, tests can still be misleading or inaccurate, as different water conditions can affect the lifespan of the bacteria. *E. coli* lifespans depend on water temperature and surrounding sediments and nutrients. In temperatures ranging from 60-65 degrees Fahrenheit, *E. coli* can potentially live for four to twelve weeks in the water, especially if microflora or sediments are present for the bacteria to attach to (Chart 2000). Eventually, *E. coli* will die off due to loss of energy and environmental stress, or lake currents dissipate the organisms into innocuous concentrations (Edberg 2000). The temporality of the bacterium means harmful contamination is generally localized. Currents will move the bacteria throughout the lake; however, in doing so, the concentrations lessen and beaches become safe to use (Manley 2013). The temporal nature of the bacteria also means that harmful pollution is difficult to test for and identify, as tests can take up to 18 hours to complete, by which time the bacteria may have already died off or dissipated and thus the results no longer reflect current conditions (UVM 2013).

E. coli enters water bodies like Lake Champlain via "poorly functioning septic systems, combined sewer overflows associated with wastewater treatment facilities, domestic animals, nuisance wildlife, and agricultural runoff" (VT ANR 2013). Faulty pipes and inadequate and outdated infrastructure are the primary point sources of this contamination. After major rain events, raw sewage often bypasses wastewater treatment plants (WWTP) and is released directly into Lake Champlain due to overloading in the plants. This untreated effluent is responsible for much of the pathogen pollution found in the lake (Phillips and Chalmers 2009). Though under the Municipal Separate Storm Sewer System (MS4) of the Clear Water Act, many towns are required to switch from the existing combined sewage overflow plants (CSO) to separate sanitary and sewage systems, progress is slow. According to Bob Fischer, the WWTP manager of the Montpelier plant, the city has recently invested $16 million to remove the CSO system. Though costly and labor intensive in nature, this switch to separate sewage / stormwater pipes will ideally ensure that "rain would have no effect on the volume of wastewater going to the treatment facilities" (Fischer 2013). As climate events intensify, addressing the infrastructure of WWTPs is a crucial component to keeping *E. coli* and other harmful pollutants out of Lake Champlain to ensure healthy and consistent water quality across the three jurisdictions.

2.3 *E. coli* as an Indicator

Though most strains of *E. coli* are innocuous, its presence in a water body generally also indicates contamination with more dangerous fecal pollutants. Monitoring waters for *E. coli* to test for the many other contaminants found in fecal matter became a common indication for water cleanliness in 1890 when scientists first identified its connection to many other fecal coliform (Edberg 2005:1). Throughout the next century, scientists created testing for *E. coli* in isolation to produce a means of less expensive and more regular water quality monitoring that can be used as an indication of fecal waste, and therefore fecal bacteria or protozoa that pose a threat to human health. Though this method of testing masks specific pathogen identification (among the ones associated with *E. coli*), it is a useful indicator of general contamination and human health risk.

E. coli often acts as an indicator for bacteria like Enterococci and Streptococci. Both of these cause gastrointestinal illness but are very resistant to antibiotics, meaning symptoms may persist for longer than those caused by *E. coli* 0157:H7. In addition, the presence of fecal coliform in water could indicate giardia and salmonella, two intestinal pathogens. Giardia is a parasite that can lead to severe gastrointestinal illness, and salmonella can also lead to more severe intestinal infections, like typhoid fever (Edgewood College 2003). Although it is hard to draw a concrete correlation between concentrations of *E. coli* in water and concentrations of these more severe bacteria and parasites, testing for this one umbrella indicator continues to provide enough information on the water quality to inform recreational safety regarding various other fecal coliforms.

2.4 Beach Contamination Management

In the United States, the Environmental Protection Agency (EPA) sets a standard for safe swimming waters, which is 235 *E. coli* colonies/100 ml water. Beaches with contamination levels above this concentration need to issue a no-swimming advisory or close the beach. In the summer months, formally established beaches and parks test for standards, and publicize results through signs and notifications (EPA). At these beaches there are eight illnesses for every 1,000 swimmers, meaning that even standardized and monitored waters are not completely free of illness-borne pathogens. Although beneficial to community health, beach closures are also a point of contestation and annoyance for the public. LCBP has conducted a survey of 35 public beaches around Lake Champlain that found a total of 66 temporary closures and three closures longer than one week due to coliform bacteria between 2008 and 2011 (LCBP 2012). The entire basin benefits from the recreational opportunities of Lake Champlain and both locals and tourists cite recreation as a crucial use of the lake (Smyth et al 2007). Swimmers have access to public, governmentally run beaches, as well as private or informal swim holes on the lake. Formal beaches are more consistent in testing, posting high contaminations of *E. coli*, and closing the beaches when waters are unsafe. Informal swim spots, however, have less consistency in how

often they are tested and how stringently they are held to safe standards. In both cases swimmers still are responsible for their own decisions to follow or disregard advisories. Beaches are located around the entire lake, making recreational safety a relevant issue for all three jurisdictions. Figure 1 shows private and public beaches surrounding Lake Champlain and closures that occur at those locations to illustrate where the varying types of beaches are and where there are general trends in beach closure on the lake, especially in relation to point-sources of waste water treatment plants.

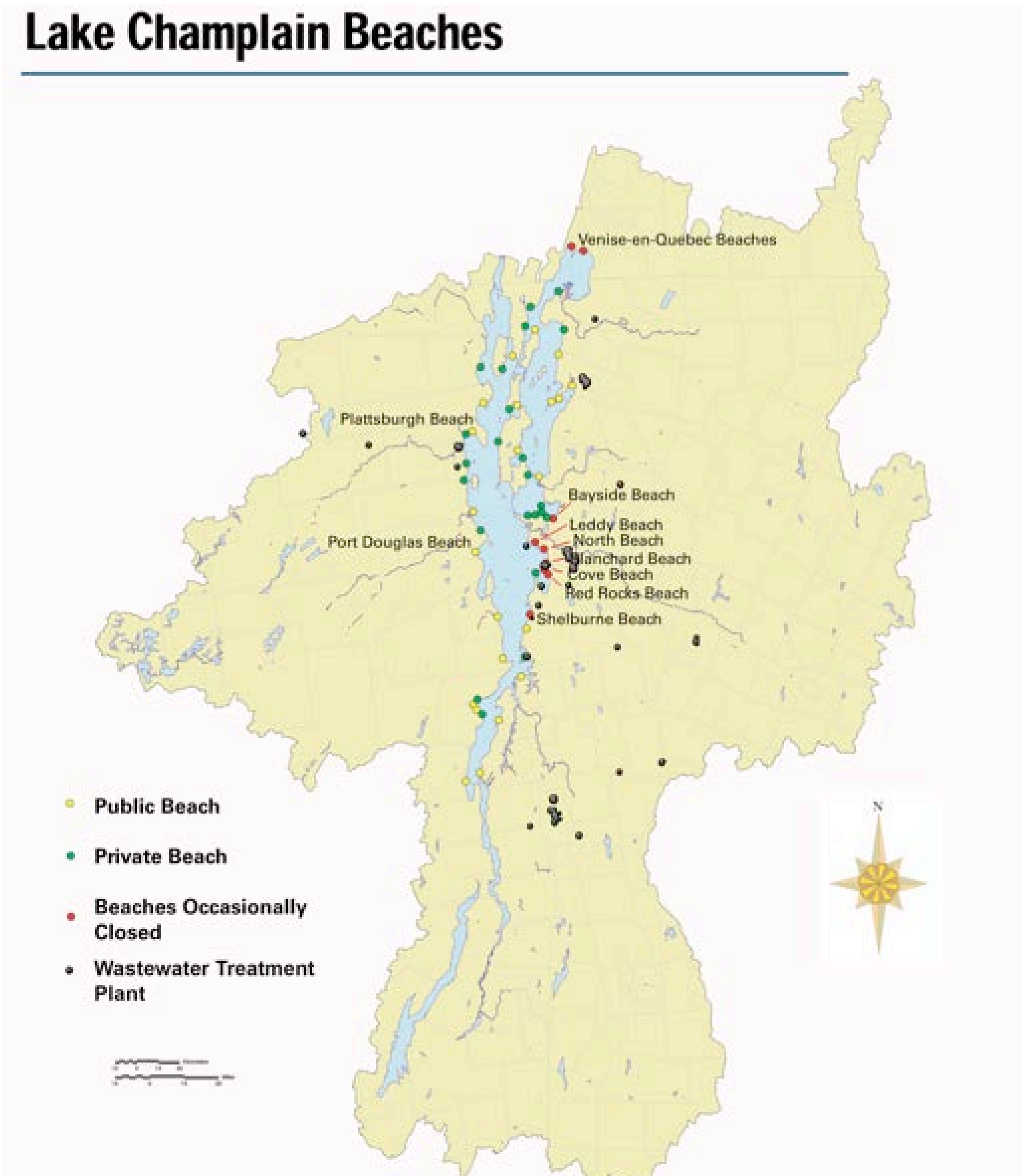

Figure 1: The location of beaches on Lake Champlain, categorized by how often they are regularly closed due to E. coli contamination. The Grey dots represent waste water facilities that serve as more definite point sources for E. coli contamination (Base image LCBP.org).

Treating *E. coli* can mean waiting until the water disperses or the bacteria has mostly died, a process that can take up to a few weeks depending on concentration, water conditions, and water currents (Chart 2000). During this time, the public would need to avoid beaches or be especially cautious. The bacteria can be treated with chlorine that kills the fecal pathogens; however, this is a more extreme solution than waiting for them to die, as it introduces more chemicals into the water in large quantities and would be an economic burden for beaches (Edberg 2000). The most effective sickness prevention method is communication to the public about when it is safe to swim so that the public understands when waters are clean or contaminated. Information sharing and education about the dangers of *E. coli* are important in order to take the responsibility off of recreational-area managers who may not have access to accurate and frequent testing, and to make residents, who may ignore advisories on *E. coli* contamination, responsible for their own health.

Ideally a swimmer, or someone advising the swimmer, would be able to recognize the connection between a recent storm and the possibly harmful concentrations of *E. coli* and other pathogens on beaches. However, this correlation still leaves room for subjectivity and the potential for misguided choices. As noted in a report published by the Vermont Agency of Natural Resources, “laypeople in the community often rely on a sensory-related approach [to identify water quality problems], for example, the smell of the look of the water or shoreline, which is then related to people’s ability to use the water” (VT ANR 26). It is important to educate a dispersed public so that individuals may be self-regulators rather than use vague results from infrequent tests to inform their decisions.

3. WATER QUALITY MANAGEMENT FOR *E. coli* IN LAKE CHAMPLAIN

Section 3 describes the current pollution of E. coli in Lake Champlain before detailing WQM classification and standards from the perspective of the three jurisdictions. Analyses of how the three jurisdictions compare their standards and goals help to describe the state of transboundary collaboration in the lake.

3.1 State of *E. coli* in Lake Champlain

The federal Clean Water Act requires states to biennially prepare a list of impaired water bodies, known as the 303(d) list. States are then required to develop and implement Total Maximum Daily Load (TMDL) plans to combat the problem. States also prepare lists of priority water bodies that suffer from pollution but are excluded from 303(d) if they require further testing or they have completed and approved TMDLs. Figure 2 shows waters within the Lake

Champlain basin in Vermont and New York that have appeared on the most recently available 303(d) and priority waters lists for *E. coli* and pathogen contamination.[1]

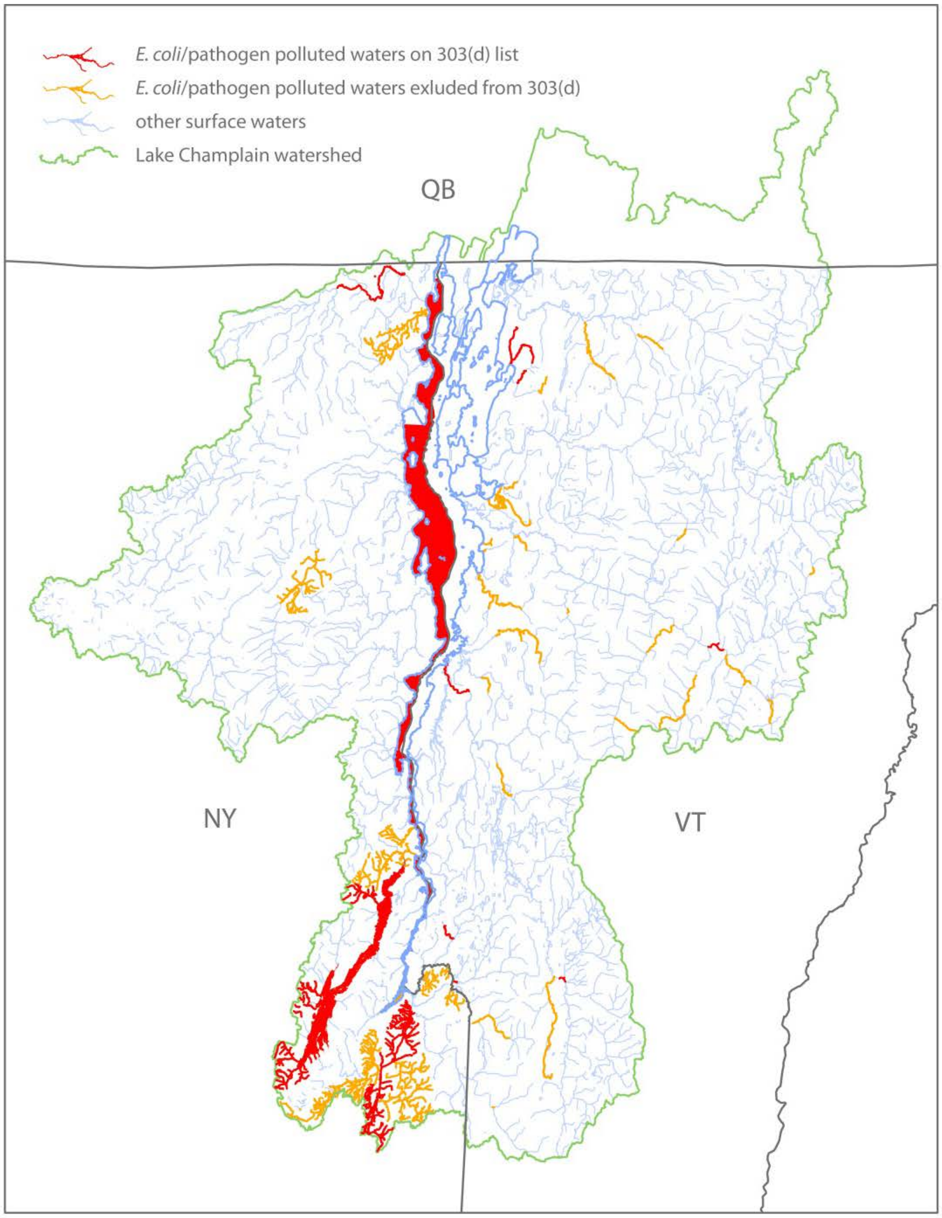

Figure 2: This map shows E. coli-polluted waters in the Lake Champlain Basin. The watershed is shown spread across Vermont, New York, and Québec, with the lake running down the state boundary in the middle. Data sources: administrative boundaries and basin boundary from \\splinter\data; Lake Champlain hydrology and Vermont water quality data from Vermont Center for Geographic Information (vcgi.vermont.gov); New York water quality data from NYS GIS Clearinghouse (nys.gis.gov).

[1] Vermont lists waters impaired because of *E. coli*; New York lists waters impaired because of pathogens. Note that in Vermont the most recent lists are from 2012, while in New York, the most recent available data is from 2010.

Figure 2 shows that *E. coli* and pathogens indeed are current problems in the Lake Champlain Basin. In addition to visually representing the extent of *E. coli* pollution in Lake Champlain, this map demonstrates the lack of coordination across the lake in relation to even one pollutant. The New York portion of Lake Champlain appeared on that state's 303(d) list, while the Vermont portion did not. This could indicate that pollution in the lake is more serious on the New York side, but more likely, it indicates that the two jurisdictions have different methods and standards for determining impairment, presenting an opportunity to improve standardization across the lake to increase accurate information-sharing.

Groups concerned with water quality management, such as governmental departments like the Vermont Department of Environmental Conservation (VT DEC) and interest groups, like the LCBP, use testing and data to prioritize pollution problems and develop plans to improve or maintain the state of the lake (ANR 2012). Water quality testing is performed in a variety of ways in the basin, depending on the use of the water source and the locations of testing, which range from state parks to municipal streams (Swift 2013). If a water body fails to meet state water quality standards, it can be placed on a statewide list of impaired water bodies. The information produced at local levels also informs the planning process for water quality management and regulation (Underwood 2013). According to Ethan Swift of the VT DEC, testing and planning on a sub-basin level can be more effective, because strategies are localized and formed by individuals with deeper connections to the specific area. At the same time, this approach also decentralizes policy and coordination (Swift 2013).

3.2 Classification Systems: Foundations of Water Quality Management

As mentioned before, Vermont, New York and Québec have varying regulatory goals for Lake Champlain that impact how each jurisdiction manages its portion of the water body and the standards they set for water quality, including levels of *E. coli*. In Vermont and New York, these regulatory goals are formalized in the states' water body classification systems, which categorize waters based on stated best usages. These best usages in turn drive the management of water bodies. First, the states designate best usages for their water bodies and then assign classes to them; the EPA then reviews these to make sure they meet Clean Water Act requirements. States are then required to protect water bodies for their stated uses (EPA 2011). As far as our research has revealed, Québec, or any other part of Canada, does not use this system to class water bodies.

i. Vermont Water Quality Goals and Classifications

Vermont values Lake Champlain for the variety of social, economic, and ecosystem services it provides. Vermont strives to protect and enhance the quality and usefulness of the lake and to maintain the purity of drinking water. It seeks to control the discharge of wastes and prevent degradation. It also explicitly states that water will be managed in a way "to promote a

healthy and prosperous agricultural community, to increase the opportunities for use of the state's forest, park and recreational facilities, and to allow beneficial and environmentally sound development," demonstrating the complex and broad demands the state sets for itself (10 V.S.A. § 1250).

According to Vermont Water Quality Standards Effective 12/30/2011, Vermont separates water into 2 main classes—A and B. Class A can further be subdivided into 2 categories. Class A (1) is "water managed to achieve and maintain waters in a natural condition." The best uses for these waters are swimming and other primary contact recreation, as well as boating, fishing and other recreational uses. They are suited for wildlife and aquatic habitats consistent with natural conditions and have the aesthetics of natural conditions. Class A (2) is "water managed for public water supply purposes to achieve and maintain waters with a uniformly excellent character." These waters are also suited for primary and secondary contact recreation.

The Vermont side of Lake Champlain is classed as Class B waters. It is also managed as a drinking water supply, as well as an irrigation water supply. Class B waters are suitable for primary and secondary contact recreation and provide good aquatic and wildlife habitat and aesthetic value (State of Vermont Natural Resources Board 2011).

Vermont water is classified by a combination of legislative acts and by the classification or reclassification decisions issued by the Board pursuant in accordance with 10 V.S.A 1253. After the classification of any waters has been established, those waters are managed by the Secretary of the Agency of Natural Resources or the Secretary's duly authorized representative. The Secretary may enforce classification and these rules against any person who, with notice, has failed to comply with water quality standards (State of Vermont Natural Resources Board 2011).

ii. New York Water Quality Goals and Classifications

New York classes water bodies by best usage, as Vermont does, but the classification system is more complex. New York divides freshwaters into eight categories: N, AA-S, A-S, AA, A, B, C, and D. In New York, Lake Champlain is classed as C, AA, A, and B from north to south. Class N, similar to Vermont's class A(1), is managed for "the enjoyment of water in its natural condition" (NYSDEC 2008:701.2). Its best uses are drinking, culinary purposes, bathing, fishing, and recreation. These waters support fish, shellfish and wildlife propagation and survival. Classes AA-S, A-S, AA, and A all have the same best uses—drinking, culinary or food processing, primary and secondary contact recreation, and fishing— and they support fish, shellfish and wildlife propagation and survival. These four classes are differentiated by the level of treatment necessary for the water to reach drinking water standards. Class B waters are not suitable for drinking; their best uses are primary and secondary recreation and fishing. Class C waters have similar uses, but their use for primary and secondary recreation may be limited. Class D waters have similarly potentially limited use for recreation and only support fish, shellfish and wildlife survival, not propagation (NYSDEC 2008).

These classes, however, and the water bodies assigned to them, may soon change. The NYS DEC is currently in the process of doing their triennial review of water quality standards. They are also in the process of updating the classification of many waters, including some portions of Lake Champlain. These upgrades are intended to help meet the Clean Water Act goal that all US surface waters become fishable and swimmable. They expect that many Class D waters will be upgraded to Class C or higher in 2013 (NYSDEC 2013).

iii. Québec Water Quality Goals

Québec released its first ever Water Policy in 2002. This water quality plan states Québec's commitment as a province to "environment quality and sustainable renewable resources" (MDDEFP 2002). It lays forth the framework for Québec's 33 watercourses as unique watershed agencies that are required to practice integrated watershed-based management based on the guidelines set forth by the Ministère de l'Environnement (MDDEFP 2002). Actions include implementing municipal, industrial, and agricultural cleanup initiatives, like a wastewater overflow management program. This document also mentions collaboration with the New England states in the US, noting that Québec should cooperate with international standards while "promot[ing] its own interests and vision of water governance" (MDDEFP 2002). It would appear that Québec's water policy largely concerns the St. Lawrence River, the body of water that Lake Champlain eventually flows into. Our research has yielded much less material on the Québec side of the lake than in New York and Vermont; Canadian policy documents' lack of information indicates that Lake Champlain is not Québec's primary concern, which perhaps explains the absence of more detailed information.

Whereas in the United States, classifications by best usages, such as those in New York and Vermont described above, are required by the federal Clean Water Act, no Canadian federal agency or law has similar requirements.[2] In the case of water quality, Health Canada, a federal agency akin to the US EPA, puts forth guidelines. Although Health Canada's guidelines inform and influence general Canadian water regulations, each individual province is entrusted with the ultimate responsibility of legally mandating province-specific regulations. Within each province, further regulation happens at the municipal level. Although Canada does not classify waters into different usages, it uses the term "fresh recreational waters" to refer to water bodies where there is prolonged exposure and possible ingestion of water, and offers recommendations for managing those (Health Canada 2009).

iv. Goal Coordination Across Jurisdictions

The three jurisdictions' approaches to classifying (or not classifying) waters for management differ significantly, which makes comparing their management schemes

[2] Canadian environmental policy operates differently because each province of Canada holds more legislative power than an American state.

challenging. Even within the United States, differing water body classes in Vermont and New York—as well as the differing verbal descriptions of what those classes mean—make comparison difficult. Figure 3 spatially summarizes the best usages or regulatory goals that the three jurisdictions have assigned to various portions of Lake Champlain. It highlights best uses in an attempt to analyze how the management goals of the three jurisdictions line up. This comparison shows that for much of the lake, the jurisdictions are pursuing very similar water quality goals. All of the Vermont portion of the lake and most of the New York portion (the "open reaches" in the deep main body of the lake, classed AA and the shoreline waters, classed A) are all managed for use as drinking water, primary and secondary contact recreation, and to support animal life ("fishing" in New York and "habitat" in Vermont).

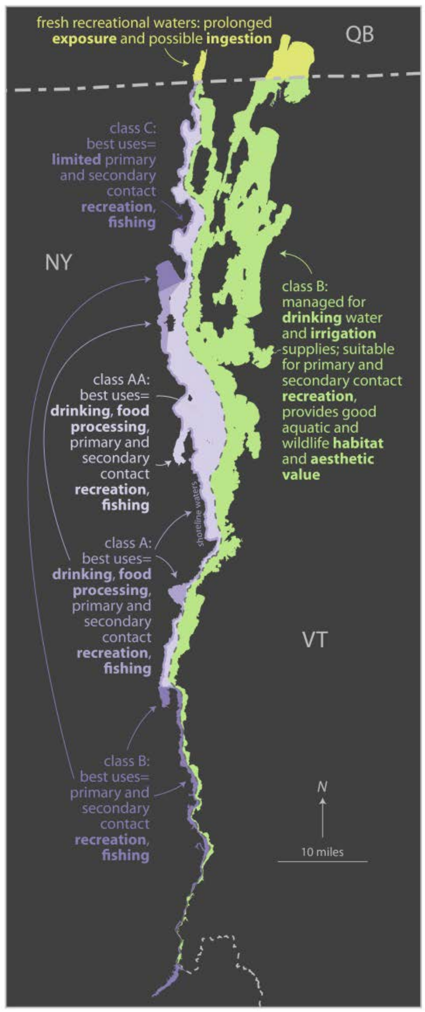

Figure 3: This map shows Lake Champlain divided by jurisdiction and by designated best uses. While most of the lake is managed for similar uses, in some areas, waters managed for different uses juxtapose. Data sources: Lake Champlain from Vermont Center for Geographic Information (http://vcgi.vermont.gov), New York classed waterbodies from NYS GIS Clearinghouse (http://gis.ny.gov/gisdata/), administrative boundaries from \\splinter\data.

There are sections of the lake, however, where the jurisdictions' regulatory goals are not compatible. In the southern portion of the lake, water managed for drinking water by Vermont mixes in the narrow channel with water managed only for recreation and fishing by New York. Similarly, in the northwestern section of Lake Champlain, water managed for drinking by Vermont lies alongside water managed only for limited recreation and fishing by New York, and only for prolonged exposure and possible ingestion (primary contact) in Québec. In these areas, coordination of regulatory objectives between Vermont and New York is weaker. These two areas are also geologically similar and the basin becomes quite narrow and the water from the two jurisdictions are more likely to mix. In these areas, it is especially crucial to coordinate management standards and policies as those in New York or Vermont might have negative implications for the other's ability to use the water for their own stated purposes. If New York does not classify water as 'drinkable' in a section of the lake adjacent to a portion that should be safe to drink for Vermont, Vermont's capacity to use the resource will be hampered. The terminology of the three classification systems also leaves much up for subjective interpretation or miscommunication as the usages are not objectively comparable.

These findings suggest that better coordination of regulatory goals of pollutants in Lake Champlain will benefit all stakeholders. Streamlining classification language on how sections of the lake are classified and addressing the discrepancies that exist across boundaries will diminish the possibility of one state's goals precluding those of another, especially where waters mix across political lines. In the instance of *E. coli*, pollutant behavior is fairly localized, and it is unlikely for contamination in one section of the lake to spread very far. However, better coordination of regulatory goals of pollutants across the board would still be beneficial, as there are many pollutants that are in fact ecologically transboundary, and spread throughout the lake, regardless of point of origin. In these instances, uniform regulatory goals between the three jurisdictions become all the more important, as they ensure public safety and health. Different and inconsistent ways of describing the goals in the classifications across jurisdictions makes lake water quality more ambiguous and less manageable.

3.3 *E. coli* Standards

In all three jurisdictions, *E. coli*, along with a gamut of other pollutants, is regulated according to the general water quality goals discussed above. In New York and Vermont, this means that each class of water has a different *E. coli* standard that all the water bodies in that class must adhere to. Further, in all three jurisdictions, *E. coli* is regulated by multiple agencies and regulatory bodies. Because *E. coli* represents a public health concern, its levels are regulated by health agencies, as well as water quality authorities. In addition, these various groups usually employ different *E. coli* standards and use different measurement strategies. These standards and measurements are summarized in Figure 4.

Regulator	Regulated Water Body	Substance	Standard (per 100ml)	Measurement Type
VT ANR	A(1) and A(2) waters	*E. coli*	18	geometric mean based on at least 3 samples obtained over a 30 day period
VT ANR	A(1) and A(2) waters	*E. coli*	33	based on a single sample
VT ANR	B waters	*E. coli*	77	based on a single sample
VT Health Department	swimming water at public recreational areas	*E. coli*	235	geometric mean
NY DEC	Class AA	total coliforms	50	the monthly median value
NY DEC	Class AA	total coliforms	240	more than 20 percent of the samples, from a minimum of five examinations
NY DEC	Class A-S	total coliforms	1000	the geometric mean, of not less than 5 samples, taken over not more than a 30-day period
NY DEC	Classes A, B, C, D	total coliforms	2400	the monthly median value
NY DEC	Classes A, B, C, D	total coliforms	5000	more than 20 percent of the samples, from a minimum of five examinations
NY DEC	Classes A, B, C, D	fecal coliforms	200	the monthly geometric mean, from a minimum of five examinations
NY DEC	Classes A-S	fecal coliforms	200	the monthly geometric mean, of not less than 5 samples, taken over not more than a 30-day period
NY DOH	bathing beaches	fecal coliforms	1000	based on a single sample
NY DOH	bathing beaches (freshwater)	*E. coli*	235	based on a single sample
NY DOH	bathing beaches	total coliforms	2400	based on the mean of the logarithms of the results of the total number of samples collected in a 30 day period
NY DOH	bathing beaches	fecal coliforms	200	based on the mean of the logarithms of the results of the total number of samples collected in a 30 day period
NY DOH	bathing beaches (freshwater)	*E. coli*	126	based on the mean of the logarithms of the results of the total number of samples collected in a 30 day period
Health Canada	fresh recreational waters	*E.coli*	200	geometric mean concentration (minimum of five samples)
Health Canada	fresh recreational waters	*E.coli*	400	single sample
QB MDDEFP	A grade public beaches	*E.coli*	0-20	geometric mean based on at least 5 samples over a 30 day period
QB MDDEFP	B grade public beaches	*E. coli*	21-100	geometric mean based on at least 5 samples over a 30 day period
QB MDDEFP	C grade public beaches	*E. coli*	101-200	geometric mean based on at least 5 samples over a 30 day period
QB MDDEFP	D grade public beaches	*E. coli*	>200	geometric mean based on at least 5 samples over a 30 day period

Figure 4: This table shows the various standards for E. coli put forth by both water quality and public health regulatory bodies in the three jurisdictions, along with information about how E. coli measurements are taken. Data compiled from: State of Vermont Natural Resources Board 2011; Vermont Health Department 2011; NYSDEC 2008; NYSDOH 2011; Health Canada 2009; Ministère du Développement durable, Environnement, Faune, et Parks 2002; Lake Ontario Water Keeper 2011.

i. Vermont *E. coli* Standards

In Vermont, *E. coli* is regulated in all water bodies by the Agency of Natural Resources (ANR), and in swimming water at public recreational areas by the Vermont Department of Health. The ANR has set two standards for *E. coli* in Class A(1) and A(2) waters, one measured using a geometric mean calculation from results of many samples over a month and one just

from a single sample (State of Vermont Natural Resources Board 2011). The reason for having two standards is likely because if the authorities find extremely high levels after doing a single sample, they can act on that data, rather than waiting a month to get all the other samples in. Thus, the single sample standard is more stringent than the geometric mean standard, though the geometric mean measurement will give a more accurate reading of *E. coli* levels normalized over time.

For Class B waters, such as Lake Champlain, there is only a single sample standard for *E. coli*—77 organisms/100 ml. The Secretary may, however, by permit condition, waive compliance with this criterion between October 31 and April 1, provided that a health hazard is not created as this is a time of low recreation. The Secretary must provide written notice to the Vermont Department of Health prior to issuing the permit. Thus Class B waters are more protected during the high season for swimming and recreation, but may fall out of compliance in the off season (State of Vermont Natural Resources Board 2011).

The Vermont Department of Health recommends that swimming water at public recreational areas be tested a minimum of once a week between Memorial Day to Labor Day. If the test result for *E. coli* is greater than 235 *E. coli*/100 ml, which is above EPA standards, the Health Department recommends that the area be closed immediately. It should stay closed until the level has decreased below the EPA *E. coli* standard (Vermont Health Department, 2011).

ii. New York *E. coli* Standards

In New York, coliform bacteria, including *E. coli*, are regulated by the Department of Environmental Conservation (DEC) and by the Department of Health (DOH). The DEC does not set standards for *E. coli* in particular, but rather for total and fecal coliforms. They use a more complex set of measurement types than Vermont: a monthly median value, more than 20% of samples from a minimum of five examinations, and a geometric mean of several samples taken over a month (NYSDEC 2008). The numerical standards range much higher than those of the Vermont ANR, but they cannot be compared as such, since *E. coli* concentrations and total or fecal coliform concentrations are not the same, and because the measurement types are not the same. The New York DOH sets standards for *E. coli* in designated bathing beach waters, stating that "a sanitary survey verifies that the watershed for the beach water is free of sewage and untreated sewage discharges, or that known waste water discharges or other contamination is determined to not adversely impact water quality or beach use based upon an historical water quality model for rainfall and bacteriological quality" (NYSDOH 2011:6-2.10). If the set limits are exceeded, officials investigate the source of the pollution and decide whether to close the beach (NYSDOH 2011). DOH bathing beach standards, however, are still not easily comparable to Vermont standards, as yet another measurement type is used: a mean of the logarithms of the results of the total number of samples collected in a 30 day period. Because the DEC and DOH do not share language for describing measurement types, it is even difficult to compare these two sets of standards within New York State.

iii. Québec *E. coli* Standards

Québec's general water quality management system does not include standards for *E. coli* that apply to all water bodies, only standards for swimming areas. At the national level, the only *E. coli* standards that exist have been put in place by Health Canada which, like the Vermont Department of Health and the New York DOH, is primarily concerned with swimming safety. In regards to *E. coli* contamination in fresh recreational waters, Health Canada has established numerical guidelines for "safe water." If sampling indicates presence of *E. coli* at a higher number, Health Canada recommends implementing a public health advisory and beach closure (Health Canada 2009).

The agency responsible for water quality regulation and management in the province of Québec is the Ministère du Développement durable, de l'Environnement et des Parcs du Québec (MDDEFP). This organization has adopted a classification system to better inform residents and disseminate information about the water quality of the various bodies of water (Health Canada 2009). The Environnement-Plage program regularly tests for the presence of *E. coli* in public beaches, with a rating system that assigns these recreational areas a grade A through D. The poorer the grade, the more frequently it will be tested in a given swimming season. A "D" grade beach will receive a no-swimming advisory and a warning for the general public to refrain from recreational water activity that is conveyed via signage and flags. Advisories are entirely voluntary, so though it is certainly in the public's best interest to comply with the recommendations, there are no legal ramifications for ignoring the warnings. (Lake Ontario Water Keeper 2011; CBC News). When comparing Québec's province-specific regulations to the general guidelines published by Health Canada, it is clear that Québec strives to maintain higher standards than the national minimum suggestion.

iv. Analysis of *E. coli* Standard Coordination

Our research shows that *E. coli* standards across Vermont, New York and Québec are incomparable across jurisdictional boundaries and also across departmental divisions within each state or province. While we have been able to compile multiple numerical standards for *E. coli* from all three jurisdictions, as demonstrated by Figure 4, these numbers cannot be directly compared because they assume different measurement types (such as geometric mean, logarithmic mean, and single sample) and apply to different substances (such as total and fecal coliforms). Thus, we have been unable to determine how similar or dissimilar these standards are—or whether they are in conflict with one another—because they are fundamentally unlike. Perhaps if the standards were recalculated in each jurisdiction with the same measurement strategy, the standards would be similar and there would not be much of a coordination issue on this matter. That said, the variances in measurement type and measured pollutant seem to suggest that the methods are fundamentally different and uncoordinated across boundaries.

Uncoordinated standards could have implications for the ability of jurisdictions to reach water quality goals, especially in regions of the lake where adjacent waters are managed by two jurisdictions to comply with very different standards. In addition, uncoordinated standards may affect the public's experience of lake. Further, standards for *E. coli* are also standards for health, and we believe that health risks associated with swimming should be common across boundaries; in other words, swimmers shouldn't need to worry that in they are assuming different amounts of risk by swimming at a Lake Champlain beach in Québec versus a Lake Champlain beach in Vermont.

We understand from our community partners that communication between water quality regulators and public health officials about *E. coli* is limited. Deciding on common measurement types and substances to measure amongst departments and jurisdictions would allow the parties to talk more effectively about how similar their standards are, and what the impacts, ecologically and humanistically, might be of differing standards.

Ideally, Vermont, New York and Québec would adopt uniform measurement types and measured substances for *E. coli* standards to allow for comparable data and information on the state of pollution in the lake to thereby inform coordinated water quality management. We acknowledge that such a change would have implications for all other water bodies within a given state or province, which could generate more complication than clarity. Thus, the challenge is to create comparable measurements within one water body that are shared by differing jurisdictions, while considering the other water resources (and their standards of measurement) that each political body must also manage. With that in mind, it may be more reasonable for organizations like LCBP and LCC to conduct their own monitoring of the lake, using their own uniform procedures as informed by their knowledge of the lake. Perhaps LCBP and LCC could work with a volunteer base or monitoring officials in the three jurisdictions to execute water quality tests in a uniform way that would generate useful comparisons.

3.4 Future Concerns for *E. coli* in Lake Champlain

Increased WQM coordination in Lake Champlain is crucial, especially in light of the intensifying weather events that are likely to occur in the coming decades. One potential way to mitigate future problems with climate change would be to further examine the role of WWTP in water quality management. In the current system, WWTPs are not equipped to handle storm events of high precipitation. As a result, raw, untreated sewage is released directly into Lake Champlain. As noted by a 2009 study, "the discharge of untreated wastewater to streams and rivers by CSOs during storms can result in elevated concentrations of bacteria, nutrients, and organic wastewater compounds (OWC) in receiving waters" (Phillips and Chalmers). This study bolsters the case and urgency for a switch to separate stormwater / sewage systems. The findings reveal that for certain OWCs, "inputs of untreated sewage overcome the dilution effect from rainfall runoff during storm flows," meaning that untreated stormwater effluent endangers the

health and water quality of the lake (Phillips and Chalmers 2009). Of course, a transition away from CSO systems will not solve all water quality problems, as the switch would only alleviate contamination with OWCs that are easily removed by wastewater treatment, unlike caffeine or cholesterol. Additionally, a separate stormwater sewage system would mean that stormwater would never pass through a WWTP, which would bring in additional contaminants to the lake.

An increase in superstorms indicates that events of untreated effluent discharge to Lake Champlain will likely occur more frequently (Fischer 2013). Most wastewater treatment plants in this region have come to treat this fact and the associated fines as inevitable line items in their annual budgets for overflow fines, rather than working to prevent spillage and water contamination. Superstorms Irene and Sandy are two recent examples of how climate change is intensifying precipitation, a sobering fact that could mean more raw sewage release into the lake. This will lead to more algal blooms and underwater plant life, optimizing the conditions that *E. coli* colonies tend to fester in.

To summarize the Fourth Assessment Report (IPCC-AR4) by the Climate Change Team of Vermont Agency of Natural Resources, observed changes in Vermont’s climate over the past fifty years match those seen in New England. These changes are also very consistent with the changes projected by global climate models through 2050. During the summer, more heavy rain events, more frequent floods and associated flood damage, increased algae, increased hazards to human health including heat waves and the spread of disease, increased hazards to human safety, such as landslides, flooding, and violent storm events, and increased threat to infrastructure are predicted. Summer is of particular concern for our project because *E. coli* colonies thrive in warm summer temperatures and the increase in high rain events also will lead to more raw sewage released into the lake (Betts 2011).We recommend increased urgency of replacing the current CSO system that exists in many municipalities of Vermont as a direct action of improving general water quality. Though many municipalities have discussed replacement plans, progress is slow (Fischer 2013). By reducing (and ideally, eliminating) raw sewage effluent discharges to the lake and the many pollutants that enter through sewage overflow, monitoring for those pollutants can be more limited and lake water quality will improve overall.

Additional current action in addressing climate change includes an 18-month study on Adapting to Climate Change with Low Impact Development (LID) Stormwater Management in the Lake Champlain Basin developed by two professors from the University of Vermont. This project will explore the resiliency of LID storm water bioretention systems while considering the mitigation of existing and projected future urban runoff stressors that impact Lake Champlain.

4. THE STATE OF OTHER POLLUTANTS IN LAKE CHAMPLAIN

This section zooms out the focus of this report to inform general WQM and introduces the framework for— and data collection we have gathered on—the many pollutants in Lake Champlain.

In thinking more broadly about general water quality management, *E. coli* is certainly only one of many pollutants that threaten the health of Lake Champlain. As an unhealthy lake undoubtedly affects all three jurisdictions and their populations, we have compiled a comprehensive portrait of all known contaminants of Lake Champlain as a tool to inform further transboundary collaboration (see Appendix 7.1: *E. coli* in Context Chart). The result has brought us to the conclusion that there are many ways to consider and group pollutants, and that unconventional groupings can create new ways of moving WQM forward. We envision the table providing useful supplemental information for managers and planners that are reconsidering WQM strategies for multiple pollutants at a time, as the chart demonstrates how distinct pollutants can relate to one another.

This chart's primary intent is to provide a way to digest and consider all the pollutants of Lake Champlain, and their relationships with one another. It allows for creative thinking when addressing pollution issues in the lake. We condensed the vast amounts of information we compiled on each pollutant down to several headings, in attempts to remain succinct yet informative.[3]

The pollutants are classified by headings, which include Primary Sources, Pathways, Lake Behavior, Human Impact, and Ecological Impact. Organizing information this way allows us to see patterns and connections between pollutants that otherwise might be ignored.
The Lake Behavior heading also points to pollutants that have transboundary implications, based on how they manifest in the lake. Though *E. coli* is a fairly localized pollutant, and therefore does not cause major contentions across different jurisdictions, there are still many shortcomings in the current management framework and with transboundary coordination regarding the bacteria, as we have delineated earlier in this document. The chart alerts us to pollutants with behaviors that do have transboundary ramifications (e.g., bioaccumulation and eutrophication), which informs general water quality management in the lake, beyond the focal scope of *E. coli.* In this regard, this chart also serves to help apply the lessons we have learned from our case study of *E. coli* to other pollutants that plague Lake Champlain.

[3] At the same time, we acknowledge that there is a danger in over-generalizing WQM, because there is no silver bullet solution that can resolve all the pollution issues of Lake Champlain. Ultimately, this chart offers a compilation of information that paints a comprehensive portrait of lake pollutants, because, it does not appear that lake contaminants have ever been classified and compared to one another.

5. RECOMMENDATIONS TO IMPROVE WQM IN LAKE CHAMPLAIN

Our study of E. coli in Lake Champlain *has imparted upon us lessons on a variety of scales, from specific E. coli management, to general water quality management practices, to broader institutional collaboration. Using obstacles that we encountered throughout the project, this section offers our perspectives on how to address these challenges and improve WQM in Lake Champlain. We first put forth recommendations that could facilitate better communication and management specifically for E. coli (e.g. including public beach users who interact with the pollutant). We then consider the comprehensive portrait of pollutants and contaminants in Lake Champlain, and suggest ways to relate them to one another as a way to improve management efficiency. Finally, we reflect upon the coordination challenges facing disparate governing bodies, and offer recommendations and venues for increased collaboration.*

5.1 Re-evaluating *E. coli* as a Priority in Lake Champlain

An obstacle we have continually come across when researching *E. coli* as a case for water quality management is a lack of information on the subject. Ranging from underwhelming concern about *E. coli*'s threat, to incomplete or blocked data, the state of fecal contamination in Lake Champlain does not seem to be a priority. As a bacteria that causes illness—even "clean" standards account for a small degree of human illness—there is a need to protect swimmers who greatly value the lake for its recreational opportunities. The presence of fecal coliform in Lake Champlain is reason for concern both for the citizens who might become sick from the bacteria and also because the source of contamination points to bigger issues of outdated infrastructure combined with increasing weather intensity. Much like Remedial Action Plans in the Great Lakes, involving grassroots organizations and community members in the remediation and protection process is an important way to engage the public with *E. coli* and water pollution in general.[4] Volunteer groups already exist in the region—the Addison County Riverwatch program consists of grassroots teams that test for pollution in area rivers (Klyza 2013). While community-oriented goals increase engagement as previously discussed, testing in general has its challenges and ambiguities, and the volunteer nature of these organizations means data quality can be variable. In addition, it is hard for the public to understand the extent of *E. coli* as it is not visible in water, and those who contract illness might not link it with *E. coli* contamination. These factors mean that many are left to speculate on *E. coli* as an issue, rather than know decisively who it affects and to what degree.

[4] See appendix section 7.2.1 for Great Lakes case study

i. Recommendations for Increasing Awareness and Data for *E. coli*

One source of disinterest surrounding *E. coli* could be a lack of relatable information and data. One way to constructively contribute to data collection, while also creating a stronger connection between those who may be affected by *E. coli* and the reality of the bacterium, is to carefully crowdsource data on illnesses over time. As noted by the VT Agency of Natural Resources, while a scientifically based assessment of water quality is necessary for an effective permitting and regulatory process, "a community's assessment is often better for attracting people's interest" (VT ANR, 26). In the summer months, a website that collects user-input data on gastrointestinal illness and discomfort in relation to beaches where they could have been exposed, could prove to be a resource for tracking *E. coli* and making people more aware of pollution. Even though it can be difficult for someone to associate such discomfort or illness with any one particular cause, if sick beach-goers could link their symptoms to a beach they had recently been to, information would collect over time to indicate locations where sickness is common at certain times. To increase the data reliability for public crowdsourcing, the platform would include simple questions that could help identify *E. coli* as the source of illness. For example, having participants enter in the date of illness and the date of water contact could single out *E. coli* contamination from other gastrointestinal illnesses as there is a lag in between ingesting the bacteria and experiencing the symptoms of it; usually two to four days (EPA). In addition, simple information such as documenting what food or drink someone brought with them to the beach could help filter entries for accuracy.

This form of data collection by crowd sourcing is often called Citizen Science and has been implemented successfully by multiple organizations. Famously starting in 1900, the Audubon Society has a Christmas Bird Count in which an extensive bird census is conducted in the Northern Hemisphere by amateur birdwatchers (Audubon Society 2013). The large amount of volunteers allows the Audubon Society to collect a tremendous amount of data with reasonable accuracy in a short time frame. This impressive feat would otherwise be impossible if only professionals were involved in the process. The scientific accuracy of a Citizen Science-based *E. coli* platform may not be high enough to use this data for regulation, but it would be an important step in assessing the extent of the issue in the lake as it would provide more frequent data, and would make WQ managers and the public more conscious of where *E. coli* is in the lake, without requiring significant monetary or human resources from groups like LCBP and LCC.

Over time, this data sourcing, could map when and where *E. coli* builds up and if there are any significant patterns in the reporting cases. Especially as weather intensifies, this information could become useful in the future to understand the evolution of *E. coli* pollution in the lake. As previously noted, involving the public in data collection is not a new idea. Initiatives for volunteer testing and volunteer cleanup of waste that might enter waterways exist, hosted by the LCC and other organizations such as the Addison County Riverwatch Association that works to test waters for DEC data collection. However, it would be a shift from involving

the public in direct testing or cleanup to one that concentrates on collecting informal data for long term analysis. However, it may prove productive and effective since having swimmers log an illness onto a website is less of a commitment than testing waters for *E. coli*. Both testing and reporting can be ambiguous, but the latter could be just as meaningful in understanding bacterial contamination in Lake Champlain. Taking a different approach to managing *E. coli*—one of tracking *E. coli*'s place in the lake—in addition to using testing to inform citizens who might risk the consequences anyway, could provide more fruitful information for water quality managers by providing a picture the long term shifts of pollutants in the lake.

Crowdsourcing experiential or scientific information can also apply to other pollutants and contribute to lake management data records. Soliciting and documenting frequent and more informal observations from locals is beneficial to those who manage the lake as it increases awareness and documentation of an issue. In addition, public empowerment and consultation increase the connection between the lake and those who use it, which could then increase public awareness of—and respect for—the lake, minimizing preventable pollution on an individual level. Outreach to the public for help with data collection could be most effective through organizations such as religious communities, summer camps, and existing interest groups such as the LCC that could encourage members to participate in contributing to such a database.

5.2 Institutional Communication and Transboundary Coordination

Another significant obstacle to our project was the overarching lack of institutional communication and coordination amongst the three jurisdictions with regards to *E. coli*. Management standards were difficult to navigate and largely incompatible, making it impossible to accurately compare them. Throughout this project, we realized that comparable data is essential to understanding and analyzing water quality management; without like data, we cannot make strong and informed analyses. The lack of feasible data analysis impairs our capacity to understand where management is effective and where it could improve.

Further, water in the Lake Champlain basin is classed differently across political jurisdictions, and within those classifications, there are differing goals for how to manage water quality. These classifications often seem arbitrary as water mixes, and they depend on political boundaries that water behavior and lake ecology do not recognize. Discrepancies in stated goals suggest varying priorities placed upon various sections of the lake and open up the possibility that one jurisdiction's goals may be precluded by another.

Lack of accessible data is another obstacle that further complicated our attempts to analyze *E. coli* management. In this report, we have attempted to compare the extent of *E. coli* contamination in the three jurisdictions (see Figure 1), but struggled immensely to locate and compile data from Vermont, New York and Québec that is comparable. Thus, we were unable to make the kind of comparisons necessary to understand the distribution of *E. coli* pollution effectively.

In many ways, all of these issues stem from lack of consistent institutional communication across political jurisdictions. For instance, management issues in the lake seem to be prioritized one at a time, with little consistent tracking of less pertinent issues, meaning non-priority issues have little or no regular coordination (Swift 2013). Karen Bates, who works at the Vermont DEC, noted that successful management relies on collaboration and consultation. Management cannot operate in isolation from other planners or successful case studies (Bates 2013). Our research on *E. coli* suggests that the current system relies on an ad hoc approach to communication where institutions only share information when absolutely necessary instead of comparing what they know and cooperating together on a regular basis to reevaluate methods and progress. This approach makes developing coordinated management of Lake Champlain extremely difficult.

i. Recommendations for Improving Institutional Communication

Though we understand that collaboration is difficult to achieve, it can be built through a consistent relationship between jurisdictions. When collaboration leads to acknowledging common values and interests, participants often find productive ways to work together and generate a greater public value than they could have achieved working alone. There are several ways institutional communication challenges might be addressed, while still keeping in mind demands and budgets of involved groups. In our specific case study of *E. coli* in Lake Champlain, a first step might be to expand upon LCBP's and LCC's transboundary work by establishing a tri-jurisdictional sub-committee focused specifically on coordinating regulatory goals and standards that meets regularly but not necessarily frequently. This committee would be composed of representatives from the environmental and public health agencies in Vermont, New York and Québec, and would meet at set intervals to discuss issues of coordinated management, especially to coordinate standards and strategies for sampling. This would provide an opportunity for increased institutional communication and create a space for developing more coordinated systems for water quality management. Perhaps the Basin Program can incorporate an additional component of public health official positions into existing conversations on management planning. There is no current venue for conversations on WQM that include public health officials, and we believe that one such opportunity should be in place. These coordinated systems could include more similar classification systems, or at least more similar best usages for shared and adjacent water bodies. Standardizing how the three jurisdictions store data would make communication smoother and more readily available for others to use and understand especially when trying to evaluate pollution and determine areas of concern. Water quality managers could better understand the extent of *E. coli* pollution or other WQM issues if the language and framework that the three jurisdictions employed were comparable.

Our research also suggests that greater coordination of water quality data collection would be helpful in bolstering and facilitating conversations about management coordination. Perhaps establishing a common spatial database where water quality data for all three

jurisdictions would be stored together in a standardized framework would help achieve this goal. All data would ideally be organized with the same attribute table structure and in the same format. In addition, the three jurisdictions would be responsible for updating the data on a specific timeline so that the most recent information would be uniformly available. Such a common database would make comparisons across jurisdictions possible, and even easy. A loose framework for such a spatial database already exists, as demonstrated in the LCBP's State of the Lake Report (Figure 5). While a good step forward in diversifying analyses and making comparisons more feasible, the current framework does not display pollution testing data. Expanding the use of spatial data to visualize pollution and testing results would be an important step in increasing accessibility of data and communication. These comparisons are indispensable baselines for understanding WQM challenges across the entire lake, and for developing coordinated management of *E. coli* or any transboundary pollutant.

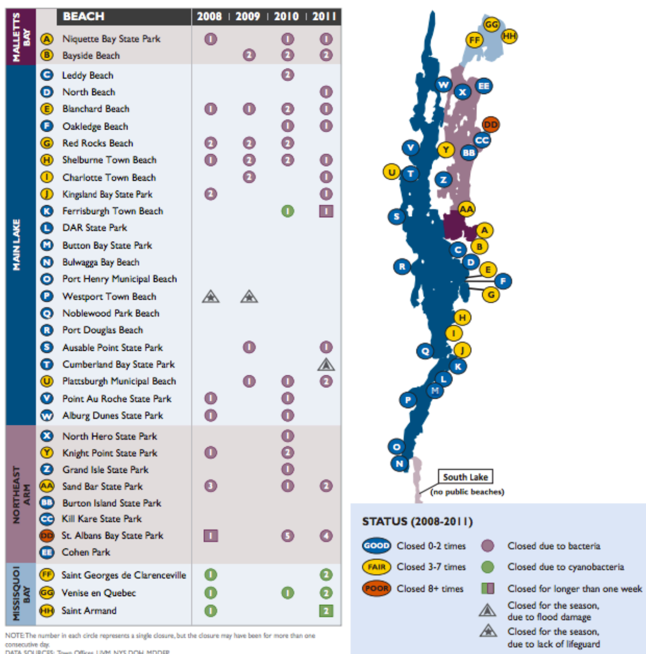

FIGURE 9 | PUBLIC BEACH CLOSUSRES ON LAKE CHAMPLAIN, 2008-2011

Figure 5. This figure, taken from the LCBP State of the Lake Report, demonstrates efforts to utilize spatial data to communicate issues in the lake. We recommend expanding upon this work to include data on testing. To do so, reporting groups and jurisdictions would need to standardize the data so that it might be comparable and usable in GIS mapping (LCBP 2012).

The difficulty in transboundary data comparison for *E. coli* serves as a fitting example of the current roadblocks in management and coordination of a transboundary resource. When considering *E. coli*, there does not seem to be a strong case for increased planning and management of the pollutant; however, there is also a lack of adequately comparable data to analyze the current state of the pollution to know if an issue does exist. Comparing and

contrasting regulation and existing standards across boundaries, even for a localized pollutant, informs managers and regulators as to patterns in pollution. Trends may then lead to more dynamic conclusions about how pollutants behave and what gaps there might be in the current management system. In many cases, samples and testing data exist for long periods of time, but again the ability to analyze these data is lacking in many cases due to the different methods and measurements. This misses an opportunity to fully learn from both the lake's current state and its ecological evolution.

In order to set up these systems of coordinated data, there also needs to be effective and consistent communication between the various jurisdictions. Again, the intensity and complexity of management leads to prioritization of issues; however, it is important to continually monitor data and come back to the table when trends emerge. Keeping in mind the financial constraints of management organizations, this framework, once set up, should be self-managing. Adding an annual review of pollution in the lake in relation to regulations and values would provide a good check-in point to understand how the lake's needs are evolving. Tri-jurisdictional groups can streamline data collection methods to distance the WQM of Lake Champlain from each jurisdiction's needs to manage a wider profile of water bodies.

This report demonstrates the immense complexity of water quality management for a localized pollutant and has provided threads of insight with which we can begin to understand the even more complex demands of transboundary management. Though there is a lack of attention given to non-pressing issues such as *E. coli*, we believe that as Lake Champlain and its resources evolve, it becomes increasingly important to implement standardized systems across jurisdictions, and to keep all issues at the table.

6. CONCLUSIONS

6.1 Redefining Transboundary

Focusing on *E. coli* has led us to reinterpret "*transboundary*" as a term that encompasses ecological, cultural, and institutional definitions. We consider *E. coli* management to be culturally transboundary, because as current policy stands, differing expectations suggest an inconsistent assumption of risk; the current definition of 'safe swimming waters' should be standardized across the three jurisdictions, but is not. Our study reveals that transboundary water quality management is not merely about political lines or ecological systems; it is also closely tied to humanistic values and institutional communication.

We can apply the lessons we have learned about the shortcomings of the *E. coli* management framework to other pollutants of Lake Champlain through abstracting the way in which pollutants relate to one another. For example, even though *E. coli* and mercury are ecologically different and have different implications for the lake, managers can learn from both of them when looking at the pollutants from the perspective of their cultural impact.

The management (or mismanagement) of mercury is also culturally transboundary, as fish consumption advisories are currently not consistent across the three jurisdictions (LCBP 2012). Mercury bioaccumulates in the fish of the lake, and as fish are not aware of political boundaries and can travel quite easily from, for example, the Québec portion of Missisquoi Bay to the Vermont portion, it is important to ensure standard fishing advisories across all three jurisdictions. Public outreach to spread information about *E. coli* in order to increase awareness and reduce health effects could be similar for mercury.

Based on the supplementary chart we have created, we can also connect mercury to other pollutants based on similar characteristics and lake behavior (see Appendix 7.1: *E. coli* in Context Chart) For example, silver, zinc, and copper fall under the same headings of Lake Behavior and Pathways as all have the primary nonpoint source origin of atmospheric deposition, and all bioaccumulate in plants and living organisms. The chart would then suggest that future management plans for contaminants like silver, zinc, or copper could be informed by those already put in place for mercury.

We approached this project with the intent to use *E. coli* as a vehicle to better understand the complexities of transboundary water quality management in Lake Champlain. Our analysis has led us to make several conclusions about water quality management as a general practice, supplemented with specific recommendations concerning *E. coli* in the lake. We hope that the report can inform readers about current contaminants that plague Lake Champlain, and also contribute a new perspective on what "transboundary" means to the discussion of water quality management in Lake Champlain.

6.2 Project Conclusions

In further developing this project, we would be interested in surveying more constituents of the lake, to better assess how to best utilize crowdsourcing potential. This also opens up an exploration of trust and user reliability. Many of our difficulties in obtaining spatial data for this project can be tied to trust. Access to Canadian data seems to be only granted upon completion of a course, which suggests that data are available, but closed off from the general public. Our challenge would be to reconcile this trust barrier with our proposed crowdsourcing platform. Our idea is currently a scaffolding of a proposal that needs further development, and we recognize that in further iterations of the platform, we need to address institutional unwillingness to publicly share data with our suggestion of creating an open-source reporting system. Surveying lake users could help hone our capacity to ask questions that would actually elicit meaningful and informative responses.

In this project, we have experienced the difficulties of establishing seamless collaboration between differing organizations which represent varying interests and diverse stakeholders. There is an intricacy in balancing stakeholder desires and resource sustainability, and the scales are often tipped in the favor of appeasing human stakeholders. Temporal sensitivity also

complicates management, as natural resource management often involves both remediation of past environmental degradation and strategic planning for anticipated problems. The key to restoring balance resides in more effective and efficient collaboration of groups that work on Lake Champlain across political boundaries. The work of LCC and LCBP is vital as they can represent Lake Champlain as a distinct resource rather that one waterbody out of many in a given jurisdiction.

From an institutional perspective, transboundary management also is most effective when both the resource is monitored and the data are stored in the same way across boundaries. This coordination means a bigger initial investment in both time and resources for groups such as the LCC or LCBP. However, as governing bodies have their own priorities, methods, and data that often conflict with one another, it is important that groups that “speak for the lake” (and not political entities) create unity in available information and data. These organizations have the capacity to take into account all of the complexities that arise from transboundary management that political jurisdictions do not. The LCC and LCBP are working towards these goals, and we hope that this report has not only provided them additional insight into *E. coli* as an issue in Lake Champlain, but that it has also highlighted areas in which they could invest to achieve a more efficient system of transboundary water quality management.

7. APPENDICES

7.1 *E. coli* in Context Chart

The table on the following pages details the general pollutants (chemical, naturally occurring, and biological) that have been found in Lake Champlain. The information draws similarities between contaminants, and informs more efficient strategies of general water quality management of the lake. It is currently grouped by similarities in Lake Behavior. Sources include LCBP: Opportunities for Action, State of the Lake; EPA; NY Dept of Health.

Pollutant	Level of Concern	Primary Sources	Pathways	Lake Behavior	Human Impact	Ecological Impact
Pesticides (Atrazine, Alachlor)	Potential Concern	Residential + commerical use, lawns, farms, golf courses, groundwater	Drainage, untreated effluent	Accumulates in living organisms, binds to sediments	Hormone level disruptor	Toxic to fish and plants
Copper	Potential Concern	Naturally occurring, trace element	Drainage, untreated effluent, historical contamination, atmospheric deposition, aquatic nuisance, natural geological formations, stormwater runoff	Accumulates in living organisms, binds to sediments	Toxic	Bioaccumulation, phototoxic, health risk to animals, negatively affects soil
PCBs (Polychlorinated Biphenyl)	High Priority	Common household items,manufacturing, coolant fluid	Fish	Accumulation in fat tissue of organisms, settles in sediment	Human carcinogen	Bioaccumulation
Ammonia	Potential Concern	Fertilizers, industrial processes	Drainage, untreated effluent	Accumulation in living organisms and matter	Direct contact irritation	Eutrophication, soil acidification, changes in ecosystem, toxic to animals
Chlorinated Phenols	Potential Concern	Pesticides, herbicides, disinfectants	Drainage, untreated effluent	Accumulation in living organisms and matter	Toxic in large quantities, affect taste / odor of drinking water	Health risk to animals
Silver	High Priority	Naturally occurring, trace element	Drainage, untreated effluent, historical contamination, atmospheric deposition, aquatic nuisance, natural geological formations, stormwater runoff	Accumulation in living organisms and matter	Brain and nervous system damage	Lethal to bacteria and other microorganisms, inhibits fungi reproduction

Pollutant	Level of Concern	Primary Sources	Pathways	Lake Behavior	Human Impact	Ecological Impact
Zinc	High Priority	Naturally occurring, trace element	Drainage, untreated effluent, historical contamination, atmospheric deposition, aquatic nuisance, natural geological formations, stormwater runoff	Accumulation in living organisms and matter	Acute toxicity: nausea and vomiting	Phytocide, toxic to flora and fauna, health risk to animals, bioaccumulation
Mercury	High Priority	Household + ag waste, improper waste disposal	Atmospheric deposition, sediment, tailings, drainage, untreated effluent	Accumulation in living organisms and matter	Harmful to nervous system, neurological damage	Bioaccumulation
Arsenic	High Priority	Naturally occuring, groundwater contamination, industrial + agricultural production	Groundwater	Accumulation in living organisms and matter	Human carcinogen	Bioaccumulation, health risk to animals
Cadmium	High Priority	Naturally occuring, fossil fuel combustion, fertilizers, cement production, municpal waste incineration	Drainage, untreated effluent	Accumulation in living organisms and matter, dwells in soil and sediment	Kidney damage	Groundwater leaching, bioaccumulation, toxic to animals
PAH (Polycylic Aromatic Hydrocarbon)	High Priority	Fossil fuels	Fuel burning	Accumulation in living organisms and matter, settles in soil and sediment	Human carcinogen	Bioaccumulation, health risk to animals
Lead	High Priority	Trace element: historical contamination, atmospheric deposition, aquatic nuisance, natural geological formations, stormwater runoff	Ships,sediment, tailings, drainage, untreated effluent	Accumulation in living organisms and matter, settles in soil and sediment	Nervous system, brain damange, kidney damage	Bioaccumulation, phototoxic, health risk to animals, ecosystem changes

Pollutant	Level of Concern	Primary Sources	Pathways	Lake Behavior	Human Impact	Ecological Impact
PBDE (Polybrominated Diphenyl Ether)	Potential Concern	Common household items	Drainage, untreated effluent	Accumulation in living organisms, acculumates in sediment	Nervous system + thyroid disruption, behavioral changes	Bioaccumulation
Persistant Chlorinated Pesticides	Potential Concern	Residential + commerical use, lawns, farms, golf courses	Drainage, untreated effluent	Bioaccumulates in animal bodies (fat soluable)	Carcinogen, nerve damange, mutagen	Health risk to animals
Dioxins/Furans	High Priority	Pesticides, industrial processes, fuel burning	Air, soil, water	Bioaccumulation, settles in water	Carcinogen	Bioaccumulation
Strong Acids and Bases	Potential Concern	Variety	Variety	Break down	Potentially toxic	Health risk to animals
E. Coli	High Priority	Fecal matter, urban and agricultral runoff	Untreated effluent, WWTP	Colonies in water, fairly localized	Indicator bacteria, 1057:H7 strain causes gastrointestinal illness	Health risk to animals
PPCP + Pharmaceuticals	Potential Concern	Personal care products	Untreated effluent, WWTP (especially those near hospitals)	Dependent on chemical makeup and metabolic pathway: some breakdown, others collect in soil and/or animal bodies	Potentially toxic	Health risk to animals
Solvents	Potential Concern	Common household items	Drainage, untreated effluent	Dependent on makeup: Methanol and ethanol based mixtures breakdown, alcohol and propane based mixtures may collect in soil and animal bodies	Toxic	Health risk to animals

Pollutant	Level of Concern	Primary Sources	Pathways	Lake Behavior	Human Impact	Ecological Impact
Blue green algae, cyanobacteria toxins	High Priority	Phosphorus, agriculture	Drainage, untreated effluent	Mass algal blooms at top lake layer, dead zones (oxygen deprivation)	Toxic if ingested in large qualities, kidney damage, osteoporosis	Eutrophication, algal blooms, health risk to animals
VOC's (benzene, acetone)	Potential Concern	Paint	Drainage, untreated effluent	Settles in sediment	Toxic	Greenhouse gas
Road salt	Potential Concern	Deicing roads in winter	Runoff, drainage	Settles in sediment, collects in water column	Unknown	Unknown
Chromium	High Priority	Naturally occuring, trace element, historical contamination, atmospheric deposition, industrial processes	Sediment, tailings, drainage, untreated effluent, stormwater runoff	Settles in soil and sediment	Toxic, skin and mucous membrane reactions	Phytocide, phototoxic, health risk to animals
Nickel	High Priority	Trace element: historical contamination, atmospheric deposition, aquatic nuisance, natural geological formations, stormwater runoff	Sediment, tailings, drainage, untreated effluent	Settles in soil and sediment	Carcinogen, respiratory irritant	Phototoxic, health risk to animals
Phthalates	Potential Concern	PVC, common household items	Drainage, untreated effluent	Settles in water	Endocrin disruption, liver problems, carcinogen	Bioaccumulation
Chlorine	Potential Concern	Treated water	Drainage, untreated effluent , WWTP	x	Respiratory irritant	Health risk to animals

7.2 Analogous Cases: Efforts to Increase Regulatory Coordination

In this project, we tried to better understand transboundary water quality issues by looking closely at two analogous cases studies. We chose The Great Lakes to highlight a working agreement between the United States and Canada over a shared water resource despite a contentious history, and Lake Tahoe to provide an example of a different bi-state relation between Nevada and California. Conclusions drawn from these case studies include a system of watershed restoration used in the Great Lakes that may be a possible solution for Lake Champlain and the true value of collaboration.

7.2.1. Great Lakes

i. Great Lake History

The Great Lakes also consist of international bodies of water shared by the United States and Canada. Much like Lake Champlain, the Great Lakes are a vital source of water for agriculture and drinking water, but on a much larger scale. The region is home to more than 30 million people in the United States and Canada and accounts for seven percent of American farm production and 25 percent of Canadian farm production, leading both countries to be highly invested in good water quality (US EPA 2008). Also like Lake Champlain, the Great Lakes are also subject to multiple beach closures during the summer months from high levels of *E. coli*.

Historically, however, political issues between the United States and Canada over water policies impeded water quality standards between 1920 and 1972 (Schulte 2011). Since then, there have been improvements and now the current system of water management between the United States and Canada under the Great Lakes Compact could serve as a model for managing water quality in Lake Champlain with its unique transboundary, whole-basin approach to water management.

This comprehensive management approach did not come immediately. During initial water policy talks for the Great Lakes Basin starting in 1905, the US did not want to relinquish political independence in exchange for regulating pollutants (Dworsky and Allee 1997). The US believed that absolute territorial sovereignty should be retained by each state for the waters within its territory and that tributaries should not be included in the Commission's authority. Canada, on the other hand, was interested in establishing an egalitarian relation across the border; Canada sought a comprehensive agreement, which would include tributaries, and a Commission with greater authority than the bodies of the past.

As a result of these political tensions, the 1909 Boundary Waters Treaty was severely limited and had little influence on the water quality of the Great Lakes. This said, the treaty also created the International Joint Commission (IJC), which examined water quality issues on a case-by-case basis and made non-binding recommendations to the two nations; the commission continues to exist today (Schulte 2011). In the treaty, transboundary waters were defined as waters that actually form the boundary between the two countries in the treaty. The treaty also

reserved the right of each country to govern its waters "which in their natural channels would flow…across the boundary." Thus, both countries could affect rivers that flow across the boundary with little concern for the downstream effects, developing a system with no redress for upstream pollution contaminating downstream waters.

Concerns over bacteria like *E. coli* in the Great Lakes date back as far as the early 1900s. Between 1912 and 1914, the International Joint Commission conducted a massive bacteriological study of pollution in the boundary waters of the United States and Canada (Durfee and Bagley 1997). It was followed by another study of current and proposed sewage work. In 1919 Canada and the United States asked the IJC to create legislation to address the apparent transboundary pollution problem. Canada expressed interest in a treaty to control pollution, but ultimately the United States declined and the topic of bacterial pollutants was left unaddressed for nearly fifty years (Durfee and Bagley 1997). Though it was in both countries' best interests to lower pollution levels in the Great Lakes, no international agreement or legislation was passed.

One of the first steps after 1920 towards increased water quality in the Great Lakes was the passage of the Great Lakes Basin Compact of 1968 (Schulte 1999). This created the Great Lakes Commission, a US body designed to collect data, publish reports, and make non-binding technical and policy recommendations related to water management in the basin. This paved the way for the passage of the Great Lakes Water Quality Agreement in 1972 and ultimately the establishment of plan to restore areas damaged from pollution. Both countries had anti-pollution programs domestically, but an international agreement proved complicated to work out even though relations had improved between the two nations. Coordination issues and political issues plagued efforts to create comprehensive, holistic water standards.

ii. Great Lake Areas of Concern

Further work in addressing transboundary pollution led to classifying areas of severe environmental degradation as Areas of Concern (AOCs). This terminology emerged from the US-Canada Water Quality Agreement 1987 Protocol, an agreement that placed more emphasis on the ecological health of the water systems than previous policy had. This protocol defined 43 Great Lakes AOCs, five of which are geographically shared by both nations. For a body of water to qualify as an AOC, any one of 14 beneficial uses must be impaired including water consumption, wildlife health, restrictions on fish and wildlife consumption, and beach closings from high levels of *E. coli*. AOCs are determined by a committee made up of members from both the US and Canada.

After an area has been classified as an AOC, the two federal governments cooperate with state and provincial governments to develop and implement a Remedial Action Plan (RAP) for each Area of Concern within the Great Lakes Watershed, with the goal of improving water quality over time. RAPs are a unique approach to improving water quality since they model grassroots environmental democracy that stresses empowerment to the public in affected AOCs. In successful RAPs, the public is strongly involved and their input is valued by state and federal officials in shaping policy. An area's chosen RAP is usually specially designed for the affected

area and is highly variant (EPA 2012). RAPs feature heavy federal, state, and local involvement in the decision making process, with an emphasis on public involvement and a multi-media approach to increase awareness and understanding.

The results of Areas of Concern have been promising. So far in total, five water bodies have been entirely de-listed: three Canadian AOCs and two US AOCs (EPA 2013), and other areas have had functions improve and have been partially restored through cleanup efforts. Significant progress has been made in the cleanup of persistent toxic chemicals. Lake Champlain, due to its lack of legacy contamination from industrialization that the Great Lakes has, may show even more improvement with the creation of a system similar to Areas of Concern. Part of the effectiveness of AOCs stems from increased coordination across jurisdictions, especially internationally. Establishing international AOCs is perhaps one possible solution to transboundary water management. The list of Impaired Water Bodies currently used, only applies to domestic waters in the United States and is not inclusionary of international water quality issues. The list of impaired water bodies in the United States highlights areas that are not meeting water quality standards, but a more international approach like Areas of Concern will highlight areas beyond jurisdictional boundaries and provide a better coordinated international transboundary approach that may be beneficial to Lake Champlain.

Stakeholder investment in Lake Champlain is greatly different from investment in the Great Lakes, where both the US and Canada are highly dependent on withdrawing clean water. Lake Champlain has unequal investment amongst jurisdictions, with Vermont being the most invested. However, perhaps highlighting international areas of concern within Lake Champlain could better improve environmentally degraded areas and prompt a joint effort across state and national boundaries to improve and coordinate management strategies.

Despite the impressive size of the Great Lakes, the watershed is relatively small (Winslow 2013). Lake Champlain on the other hand has a much larger watershed, which increases the potential for watershed pollution from both point source and nonpoint source pollution even though it is much less industrialized.

Under current policies, the situation in the Great Lakes has improved greatly. Multiple agreements have been passed between 1972 and 2005, increasing water protections in the Great Lakes. The current collaborative international system of managing water quality within the Great Lakes has been hailed as a success over the years, partly because of its approach to embracing both countries’ political systems and working to respond to environmental degradation (Dworsky and Allee 1997). Previously, tensions between the two countries over differing goals impeded water quality management in the Great Lakes, despite it being in their best interests to cooperate with one another; however, inherent flexibility within the agreement permits the IJC to adapt to new, unexpected situations as a result of new information or changing circumstances. In summary, the establishment of Areas of Concern in Lake Champlain may prove fruitful since they serve to highlight international areas that are environmentally degraded and provide a useful way for communication and local involvement.

7.2.2 Lake Tahoe

i. Background

Located along the border between California and Nevada, Lake Tahoe sits within the Sierra Nevada Mountain Range. Approximately two-thirds of the shoreline is in California while the remainder lies in Nevada. The lake is 12 miles wide and about 22 miles long. 63 streams feed into Lake Tahoe, but only one, the Truckee River, flows out. Though there are 66,000 Tahoe Basin year round residents, approximately 3 million people visit Lake Tahoe every year due to its ski resorts, summer outdoor recreation and tourist attractions. Like Lake Champlain, the lake is a major source of drinking water. In fact, about 50% of the residents in Lake Tahoe obtain drinking water from the lake (TWSA 2013).

ii. Lake Tahoe and the History of Bi-State Relations

Though Lake Tahoe does not share international borders, it serves as a relevant case study for Lake Champlain due to its Bi-State relations between Nevada and California. Lake Tahoe demonstrates that a "networked" approach to watershed governance can be effective. Lake Tahoe also demonstrates that watershed governance, by its transboundary nature, is likely to involve complex institutional arrangements where some decisions are centralized and others highly decentralized. Also, given the US federal system and the fact that there will always be overlapping centers of authority, Lake Tahoe illustrates the strong role that nongovernmental organizations have in a governance system that increasingly relies on nonregulatory policy instruments.

These joint actions included local governments becoming increasingly willing to work with the Tahoe Regional Planning Agency (TRPA) to streamline the permit process. Today, the Lake Tahoe Environmental Improvement Program (EIP) has a momentum of its own attracting new partners and resources. Moreover, as the partners learned how to work together to implement the EIP, the pace of activity increased. Organizations overcame their differences and achieved the threshold level of success necessary to develop and implement the EIP through collaborative know-how and increased trust.

The many contentions in the past were costly to both government and non-government agencies, but it also increased discourse between the stakeholders. While watershed management encourages practitioners to view ecosystems holistically, collaboration is inherently strategic and is unlikely to be an appropriate strategy for addressing controversial problems involving win-lose situations. Lake Tahoe demonstrates that when collaboration highlights common values and interests, participants often find productive ways to work together and generate greater public value than can be achieved by working alone (Imperial 2003).

iii. Lake Tahoe Today

Today, the federal government continues to play an active role in the preservation of the lake environment. Stakeholders of Lake Tahoe include the USDA Forest Service, as they manage approximately 80 percent of the land within the Tahoe Basin. State agencies also manage five percent, so the partnership between the TRPA and federal and state stakeholders is extensive. Their collaboration is most evident in the Lake Tahoe Environmental Improvement Program (EIP). The EIP is one of the primary strategies involved in achieving environmental thresholds and is a public-private partnership. More than 50 public and private organizations have worked on the Lake Tahoe EIP. The EIP is funded by the financial support from the federal government, the states of California and Nevada, local jurisdictions in the Tahoe Basin, and private homeowners and businesses.

Though the joint planning is useful in collaboration, contentions still run high. Two years ago Nevada make a threat to pull out of the TRPA in an effort to make different parties come to the table and negotiate a more balanced planning and permitting process. Today, Nevada has decided to withdraw from the bi-state TRPA and will likely leave in two years. This move resulted in part from conservative, pro-business forces in the legislature and long-standing unhappiness with the way development has been regulated at the lake, as well as TRPA's failure for decades to update a major planning document. Job creation was an additional concern.

Though the lake is currently the clearest it's been in the past 10 years, these relations are not getting any better. Therefore, it will be interesting to watch the bi-state compact between Nevada and California and see how the contentions perhaps help further build the community or destroy it (Howard 2013).

iv. Lake Tahoe Conclusion

With the bi-state TRPA falling apart and Lake Tahoe's long and controversial regulatory history, this watershed is an excellent illustration of the changing nature of federalism, local capacity-building, and incentives for solving environmental problems. While the bi-state compact may not have worked out, it did provide a basis for discussion and some well-run groups have successfully come out of it. Pollutants like *E. coli* will be monitored in depth with the creation of the Tahoe Center for Environmental Sciences. Perhaps a lesson that can be gleaned for Lake Champlain is the collegiate partnerships that Lake Tahoe employs, so the amount of pollutants entering the lake can be researched, monitored, and modeled more fully by a consistent group of people.

As Lake Tahoe clearly demonstrates, there will be limits on practitioners' ability to use collaboration as a strategy for improving watershed governance. Conversely, Lake Tahoe demonstrates that when collaboration highlights common values and interests, participants often find productive ways to work together and generate greater public value than can be achieved by working alone.

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